Draft Test Plan

Assessment of the Emissions from the Use of California Air Resources Board Qualified Diesel Fuels in Comparison with Federal Diesel Fuels

Chassis Dynamometer Testing

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1. Objective

California has had in place a diesel fuel regulation that promotes and mandates clean burning diesel within the state. Recently, Federal diesel fuel regulations have been modified to reduce sulfur levels to accommodate advanced diesel engines and aftertreatment systems. The objective of this test program is to better understand and quantify the benefits of continued use of CARB diesel fuel in the State. This test program will compare CARB diesel fuels with Federal diesel fuels over a range of vehicle technologies. The primary testing will be conducted using both heavy-duty engine and chassis dynamometer testing at the University of California at Riverside. A total of 3 fuels will be tested, including a fuel designed to represent an average CARB ultralow sulfur diesel fuel and 2 Federal ultralow sulfur highway diesel fuels, on at least three heavy-duty on-road engines and a fleet of in-use vehicles. Both the engines and the vehicles will include a range of engine/vehicle technologies that are representative of California's in-use fleet. The focus of this test plan is to describe the test methods that will be utilized for the chassis dynamometer portion of the testing.

2. Stakeholders

For the purposes of this study, an Advisory Panel has been convened. The Advisory Panel consists of interested parties, including representatives from government, industry, and academia. The Advisory Panel has assisted in the development of the test matrix of fuels, engines, and vehicles.

3. Test Fuels

A total of three fuels are being used for this test program. These test fuels included one representative CARB ultralow sulfur (CARB) diesel fuel and two Federal ultralow sulfur highway (Federal) diesel fuels. One of the Federal diesel fuels, referred to as "Federal A", represents an average Federal ultralow sulfur diesel fuel. The second, referred to as "Federal B", was a commercially available Federal ultralow sulfur diesel fuel that due to its properties may contribute to higher exhaust emissions.

The CARB-certified ultralow sulfur diesel (ULSD) fuel is the baseline for testing. The CARB fuel was obtained from a California refinery. The properties of the fuel were reviewed by CARB staff prior to selection to ensure they were consistent with those of a typical ULSD in California. The targeted properties included aromatics, API gravity, and cetane number.

The Federal A fuel was obtained directly from a specialty fuel provider, and is a federal emission certification fuel. This fuel was selected because it has properties which represent an average federal diesel fuel.

The Federal B fuel was obtained from a commercial retailer outside of California. It is heavier than the Federal A fuel, having a lower API gravity, higher aromatic hydrocarbon content, and lower cetane number than the Federal A fuel.

The fuel property ranges targeted for the three test fuels were based on CARB's Fuels Enforcement data, a California Energy Commission (CEC) refinery survey, Alliance of Automobile Manufacturers' North American Fuel Surveys, a Northrop Grumman Diesel Fuel Oil Survey, and additional proprietary fuel survey data. The fuel property ranges were discussed and approved by the Advisory Panel.

Fuel analyses for the six targeted fuel properties along with ASTM D975-specified properties have been conducted on the CARB and the two Federal diesel fuels. The analyses were conducted in triplicate. The majority of the analyses were conducted by CARB in their fuel laboratory in El Monte, CA. The cetane number analyses were conducted at the Southwest Research Institute (SwRI) in San Antonio, TX. A summary of the averaged results of the analyses for the selected properties of the test fuels is provided in Table 1.

Table 1. Selected Fuel Properties

	CARB ULSD	Federal A Diesel	Federal B Diesel
API gravity (@ 60ºF)	36.8	35.2	34.0
Aromatics, vol. %	19.1	30.6	36.0
Cetane number,	50.4	45.5	44.1
Distillation, IBP			
T50,ºF	477	487	493
T90, ºF	606	581	618
Sulfur, ppm	7	13	5

4. Chassis Dynamometer Vehicle Selection

A fleet of 10 vehicles will be selected for the chassis dynamometer testing to help verify any trends observed from the engine testing. The test matrix is designed to represent a range of different model years, certification levels, and technologies. The test matrix is provided in Table 2, based general model year groupings that correspond with certification categories.

Table 2. Vehicle Test Matrix

1991-1993	1 vehicle
1994-1997	1 vehicle
1998-2002	2 vehicle (UCRs 2000 Caterpillar C-15 + 1 retrofit)
2002-2006	3 vehicles (one will be 2006 Cummins ISM + 1 retrofit)
2007-2010	2 vehicles (one will be 2007 MBE4000)
2010+	1 vehicle

Three of the vehicles selected for testing will be vehicles equipped with engines either being tested in the engine dynamometer portion of this test program and/or the chassis dynamometer portion of the associated CARB biodiesel study. The specification for these engines is provided in Table 3.

Table 3. Test Engine Specifications

Engine Manufacturer	Cummins, Inc.	Detroit Diesel Corp.	Caterpillar
Engine Model	ISM 370	MBE4000	C-15
Model Year	2006	2007	2000
Engine Family Name	6CEXH0661MAT	7DDXH12.8DJA	XH0893ERK
Engine Type	In-line 6 cylinder, 4 stroke	In-line 6 cylinder, 4 stroke	In-line 6 cylinder, 4 stroke
Displacement (liter)	10.8	12.8	14.6
Power Rating (hp)	385 @ 1800 rpm	420 hp @ 1750 rpm	475 hp @ 2100
Fuel Type	Diesel	Diesel	Diesel
Induction	Turbocharger with charge air cooler	Turbocharger with after cooler	Turbocharger with after cooler

The remaining 7 vehicles will be obtained via a variety of other potential strategies. CE-CERT has conducted a number of programs that have required recruitment of class 8 trucks for in-use testing. CE-CERT has used various means of recruiting for this program including advertisement, local rental agencies, private owners that are accessed from local repair and other truck service industries, and through programs associated with the ports of Los Angeles and Long Beach. Currently, our contacts at the Port of Los Angeles have indicated that there is a high probably that they can supply the vehicles needed for this project from fleet owners associated with their operations. Additional strategies may also be deployed for the recruitment of buses, including working with local municipalities or recruiting through the University of California fleet system. The budget incorporates a nominal amount of resources for the recruitment of vehicles, rental charges, and finders or usage incentives as needed.

5. Chassis Dynamometer Testing

Chassis dynamometer testing will be performed at CE-CERT using a heavy-duty chassis dynamometer. The chassis dynamometer will be a 48” electric AC chassis dynamometer with dual, direct connected, 300 hp motors.

Prior to conducting the chassis dynamometer testing, coast down procedures will be performed on each vehicle to all the determination of this road load coefficients. The coast downs will be performed at the test weight that will be utilized for the actual chassis dynamometer testing. The three vehicles that were utilized for the biodiesel program were all coasted down and tested as part of that program. To allow for a better intercomparison between this program and the biodiesel program, the same coast down values and test weights used in the biodiesel program will also be utilized for this program. The based on the biodiesel testing, the test weights for the 2000 Caterpillar engine truck, the 2006 Cummins engine truck, and the 2007 MBE4000 engine truck will be 58,744 lbs., 66,000 lbs., and 57,490 lbs., respectively. The remaining vehicles will be coasted down using CE-CERT’s Mobile Emissions Laboratory (MEL) as the test weight.

This will provide a total load of approximately 65,000 lbs., which is approximately the average weight of a truck being used in California.

Testing will be conducted on each vehicle/fuel combination using the ARB 50 mph HHDDT cruise cycle. Initially, several test cycles were proposed to represent additional types of roadway driving conditions. However, since resources are limited and test-to-test variability is historically somewhat greater as compared to engine dynamometer testing, the ability to increase the number replicates per fuel type was deemed more significant than the inclusion of an additional test cycle.

The test matrix is designed to include 12 test iterations of the ARB 50 mph HHDDT cruise cycle on each fuel for each vehicle. The test matrix is randomized so that it includes replicates of the baseline CARB diesel fuel at various times throughout the test period. Due to the time constraints of the program, it is planned to conducted a compressed 3 day testing schedule. This same matrix would be repeated for each vehicle tested. All tests will be hot start tests and each days testing will begin with a vehicle warm up period prior to the start of the appropriate test cycle. The test matrix for the chassis dynamometer testing is provided below in Table 4.

Table 4. Chassis Dynamometer Test Matrix
For each Test Vehicle

Test Day	Morning Schedule (assumes 6 replicates)	Afternoon Schedule (assumes 6 replicates)
ARB HHDDT Cruise Test Cycle		
Day 1	CCC AAA	AAA BBB
Day 2	BBB CCC	CCC AAA
Day 3	AAA BBB	BBB CCC

C = CARB diesel fuel, A = Federal A diesel fuel, B = Federal B diesel fuel

The emissions sampling for the chassis dynamometer will utilize CE-CERT's Mobile Emissions Laboratory. For all tests, standard emissions measurements will include THC, CO, NO_x, NO, CO_2, and PM.